UNIVERSITY OF FLORIDA
EXTENSION
Institute of Food and Agricultural Sciences

CIR702

A First Look at Florida Aquaculture [1]

Jerome V. Shireman and William J. Lindberg[2]

Foreword

This Extension circular is a revision of the Florida Aquaculture Plan submitted to the Florida Legislature by the Commissioner of Agriculture in accordance with the Aquaculture Policy Act of 1984. That plan, originally drafted within IFAS Department of Fisheries and Aquaculture, was prepared by the Florida Aquaculture Review Council and the Aquaculture Interagency Coordinating Committee. Participants in these groups are acknowledged on page I, and we sincerely thank them for their many contributions.

The purpose of this circular is to educate citizens about aquaculture in Florida, its current status, and its prospects for future development. In contrast to the state plan which emphasizes what government agencies should do to facilitate aquaculture development, this bulletin concentrates on general information of interest to persons considering entry into aquaculture. Much of the information has been provided by cooperating industry leaders, in addition to being taken from university and government reports. Assertions made in this publication about the risks or future prospects for a given type of aquaculture reflect professional opinions of persons contributing to the Florida Aquaculture Plan, and may change as technical, regulatory, or economic conditions change. We encourage you to use this publication simply as an introductory guide on your way toward making fully informed decisions about Florida aquaculture.

Jerome V Shireman

William J. Lindberg

May 1985

Introduction

Florida's semitropical climate, long coastline, and abundant water supplies in certain areas make it an ideal state for aquaculture. State law defines aquaculture as the cultivation of animals and plant life in a water environment (Chap. 253.67 (1) F.S.), which implies that the organisms are grown in water, the natural habitat of the organisms is water, and some part or all of their life cycle or culture period is influenced or manipulated by man. The degree to which the life cycle and environmental needs of an organism are controlled by the culturist may range from simply relaying coon oysters for grow-out on a leased site to artificially maintaining fish from egg to harvestable size in a tank. Aquaculture may be undertaken to produce food and fiber (both plants and

1. This document is Circular 702, Department of Fisheries and Aquatic Sciences, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. First published September 1986. Revised February 1996. Reviewed March 2000. Please visit the EDIS Web site at **http://edis.ifas.ufl.edu**.

2. Jerome V. Shireman, Chairman, and William J. Lindberg, Assistant Professor, Department of Fisheries and Aquaculture, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

animal) for human consumption, bait and stockers for recreational fishing, ornamental fish and plants for the aquarium hobbyist, juveniles for enhancing natural fisheries, and raw materials for energy and biochemicals. In Florida, aquaculture could be considered as an alternative use of land that was previously unsuited for traditional agriculture or as a highly intensive, diversified crop for small landowners. Aquaculture is not a new industry . Asian and European fish culture systems h-ave existed for centuries. Although aquaculture is a large and growing industry over much of the world, it is relatively new and undeveloped in the United States. U.S. production contributes only about 2% of worldwide aquaculture yields. In 1975 U.S. production reached 65,000 metric tons and with proper support should reach one million metric tons by the year 2000 (National Research Council, 1978). Private aquaculture produces over 40% of U.S. oysters, most U.S. catfish and crawfish, nearly all rainbow trout, and small quantities of several other species.

The outlook for the U.S. aquaculture industry is encouraging for several reasons: 1) wild fish stocks are finite and declining because of over fishing and loss of habitat, 2) fish imports to the U.S. have increased, and 3) world demand is increasing as per capita consumption of fish is increasing. During the past 20 years, per capita consumption of seafood in the U.S. has increased almost 25% and is predicted to increase at an average rate of 3,4% annually.

Aquaculture in Florida is currency a valuable industry but traditional food species do not contribute substantially to it. Specialty items such as tropical fish and ornamental aquatic plants are important to the Florida economy. Florida is the only state where large amounts of these products are grown. Aquatic plants generate between 3.5 and 5 million dollars annually, while the annual retail value of Florida tropical fish exceeds 75 million dollars.

Florida's aquaculture potential has not been realized. Culture facilities to produce food fish, plants, and recreational fish have not been fully developed. Nevertheless, individual aquaculturists, or persons contemplating entry into this business, must carefully consider all of the elements needed for profitable aquaculture. Available natural resources must be appropriate for the species to be cultured. The aquaculture facilities and operations must conform to a wide variety of regulations, often involving permits. The products must be economically grown and effectively marketed. And of course, the life cycles of the desired species must be subject to an adequate amount of control under practical aquaculture conditions. This booklet will give you an introduction to such considerations, an overview of species with aquaculture potential, and additional sources of information.

Florida Natural Resources

Florida's climate and natural resources are well suited for aquaculture when such ventures are selected to match prevailing local conditions and to tolerate infrequent environmental extremes. For instance, mild winter temperatures with only sporadic freezes enable the tropical fish industry to flourish in the Tampa-Lakeland-Bradenton and the Miami areas. Mild spring and autumn temperatures contribute to early spawning and a long growing season. Thus, tropical fish farmers produce several crops per year. On the other hand, high temperatures and low dissolved oxygen in south Florida ponds during summer could be impediments to commercial catfish production there. Warm springtime water temperatures, however, allow early spawning so that Florida fish farmers can produce fry and fingerling stocks earlier than other U.S. farmers.

Florida has seasonally abundant water supplies, especially in the north central portion of the state. The Floridan Aquifer provides abundant ground water of high quality in some areas. In many areas, spring water from the aquifer is abundant and might be developed for aquaculture pursuits. For example, the National Fish Hatchery at Welaka receives all of its water from Blue Springs. Spring water is of high quality and has a constant temperature of 70-74°F (21-23°f). Surface water is also plentiful, and in many areas high water levels combine with soils that hold water all year round to make aquaculture practicable. The tropical fish industry centered near Tampa uses ponds of this type. Lowlands of central and north central Florida could be developed in a similar manner. The soils of the Florida panhandle

contain considerably more clay, and in these areas perched ponds are used.

In areas with abundant water supplies and soils with limited water-holding capacities, intensive culture systems could be utilized. This might apply to mariculture adjacent to high energy beaches, where seawater could be drawn in and filtered through the beach system, e.g. Marineland. However, economic constraints would likely prevail in such settings.

The diversity of conditions encountered throughout Florida dictates that a given aquaculture venture will be better suited to some portions of the state than to others. Thorough consideration should be given to such factors before initiating an aquaculture business. An excellent summary of Florida's climate, soil types, and water resources can be found in the Atlas of Florida (Fernald, E.A. 1981. Atlas of Florida. Florida State University Foundation, Inc., Tallahassee.), which should be available in local libraries or bookstores. However, general reading is no substitute for on-site surveys of soil and water resources during the planning phase of an aquaculture venture.

Aquaculture Regulations and Public Policy Issues

Aquaculture requires access to arable land, or submerged land and water resources, which are under the combined jurisdiction of local, state, and federal regulations. These regulations may range from compilation of a complex environmental impact statement involving a number of agencies to the purchase of a simple freshwater fish farm license from the local tax collector. Traditional farming began long before the initiation of regulations and so la~s governing farming evolved along with farming technology. Laws governing the hunting and gathering techniques of commercial fishermen and the protection of native and recreational stocks also evolved long before aquaculture was given serious consideration. Because aquaculture has been included with the commercial and sports fishing industries, it is often governed by commercial fishing and wildlife protection laws. The appropriate place for aquaculture in our regulatory system is currently a public policy issue.

Sea farming means farming the seas' coastal margins, bays, and estuaries, where nearly 90% of the world's food fish spawn, mature, and get captured The conditions which make mariculture attractive to a given coastal area are the same conditions which make the area attractive for people to live and play. Conflicts among competing users are a significant threat to the development of aquaculture along the coastal zone. The most significant public issue is whether or not an individual should be allowed to privately own (lease) and make a profit from a commonly held natural resource such as the sea. This will involve basic changes in the legal and regulatory system to develop this wholly new economic activity.

In 1978, the National Research Council found that constraints on the orderly development of aquaculture tend to be political and administrative rather than scientific and technological. This statement was reaffirmed in the 1983 National Aquaculture Development Plan. There are few laws designed to promote and protect aquaculture. That is, aquaculture does not explicitly fit into existing agricultural programs and, as a result, is regulated at each level of government by a number of agencies having their own range and scope through different state and federal programs. The number of agencies participating in permitting an individual aquaculture facility is often large; regulations are highly complicated and often require legal expertise to understand.

Basic information on aquaculture as an industry is not readily available; consequently, it is often unclear which regulations pertain to a specific aquacultural situation. This leaves regulators uncertain as to whether or not a permit is needed and whether or not specific rules are applicable. Many well intended laws have been written to meet legitimate public needs at local, state, and federal levels, but without consideration for aquaculture. Regulatory processes affect aquaculture in a number of areas including land and zoning regulations, water and water quality regulations, environmental, including dredge and fill, placement of structures in navigable waters and facility discharges, fish and fisheries management, facility and hatchery management, Federal Food and Drug Administration drug registration and shellfish sanitation, coastal protection, wildlife protection, introduction of

non-native species, transport of live animals, and normal business functions such as taxes, workmen's compensation, and safety.

Table 1 summarizes the regulations which currently affect Florida aquaculture. These may be subject to change as the aquaculture industry and State Legislature work to develop Florida's aquaculture potential.

Land Use Planning

Aquaculture projects using natural resources can quickly become involved in land use conflicts. Land areas which are potential locations for aquaculture can be also used for homes, agriculture, industry, and recreation. In Florida, two types of areas seem best suited for aquaculture: low relief areas and coastal areas. Nevertheless, most aquaculture development in Florida will likely occur on existing agricultural lands, uplands, and waters already approved for shellfish harvesting.

Land use conflicts associated with a growing population are a major constraint on marine aquaculture ventures requiring waterfront or shoreside facilities. The state's population of more than 10 million is increasing by 6000 people per week, and over 79% of the residents live adjacent to the seacoast. Consequently, 10 of the nation's 25 fastest growing metropolitan areas are along Florida's shoreline. Water-dependent businesses of all kinds are subject to considerable economic pressure by high-valued residential and urban development.

Even rural counties are not immune to land use problems of a burgeoning state population. Many coastal rural counties are undeveloped because they lack the high-energy beach systems attractive to high-density residential development. Those traditionally rural counties with such beaches (e.g. Flagler, Santa Rosa, or Walton) are now experiencing rapid coastal construction. The remaining counties typically have low-energy coasts with extensive fringing wetlands of mangroves or salt marshes. The value of these habitats to the natural production of marine fisheries is being recognized by the economically important and politically influential sportfishing and commercial seafood industries as well as government agencies. Aquacultural projects will face many regulatory hurdles if they are sited directly in mangroves and salt marshes. However, projects sited in waters adjacent to or along borders of such areas may prove to be compatible.

The land requirements for marine and freshwater aquaculture will be increasingly squeezed between full urban development and the preservation of already productive and/or natural habitats. Aquaculturists must be aware of the land use planning mechanisms at all levels of government and the extent to which they include provisions for aquaculture and the spectrum of water-dependent industries.

Economics

For the aquaculture industry in Florida to develop, individual ventures must operate profitably. All ventures require capital secured from private, public, and/or commercial sources. Aquaculture is generally perceived as being risky, due to the newness of the industry, the lack of adequate data to assess costs and returns, the limited number of species with proven track records, and the limited number of persons with necessary management skills. Profitability is therefore difficult for a lender to assess, and consequently the necessary capital may be difficult to obtain.

The large amounts of energy, materials, and capital often necessary for an aquaculture venture add to the industry's high risk profile. Start-up costs to purchase land, construct ponds and buildings, and drill wells are considerable. Intensive culture systems, although requiring less land, are costly to construct, require more energy to operate, and require greater management skill. Feed and labor costs are high and account for the majority of operating expenses. Interest rates are high and a period of time must pass before the product is harvested and cash flows into the operation. security must be provided to prevent theft. Insurance underwriters lack the expertise to assess risks and have too few aquaculture businesses among which to spread the cost of the risks. Regulations are both costly and time consuming, diverting considerable entrepreneurial energy away from the main focus of establishing a business. Each of these factors creates an added risk to an aquaculture venture, making the securing of a loan difficult.

Commercial banks are aware of these risks and are generally not yet considered to be a prime source of capital. Public sources include the Farmers Home Administration, Farm Credit Administration, and Small Business Administration. These sources may be adequate for small and intermediate size operations, but do not completely cover all start-up and operating costs, and must be supplemented with other sources of capital. Private sources include family loans and personal savings which are usually inadequate for a full scale operation. Venture capitalists will accept the higher risk, but require a high and rapid rate of return on their investment.

When planning an aquaculture venture, financial considerations must receive as much, if not more, attention as the technical and biological aspects of production. Additional economic decision-making information is available through the Cooperative Extension Service or Sea Grant Extension Program.

Marketing

Markets and market potentials for food fish produced on Florida aquafarms are not established. Florida freshwater aquaculture products are sold in Florida primarily by small firms with sales made through private negotiations. Marketing of food fish is complicated because few processing plants exist in Florida for freshwater aquacultural products, whereas processing and wholesaling plants for marine products are common. A major portion of the marine species landed in Florida are sold directly to out-of-state buyers. Overall, at least 60% of total products are exported; however, Florida is not self-sufficient in seafood production, e.g. two-thirds of the shrimp processed in Florida were imported to Florida for processing.

It is evident that processing plants and market corridors exist for marine seafood products. Mariculture products could fit into this marketing scheme, provided that costs to produce these organisms do not greatly exceed the cost of wild caught products. Alternatively, cultured species could enter the market during off seasons or a profit could be made by buying and reselling from freshwater processors. It is difficult for us to predict if freshwater cultured species such as catfish could enter the current Florida seafood market. Catfish, although a popular product in the Mississippi River delta area, has not been cultured extensively in Florida. This small industry has relied upon local sales outlets. It is doubtful that catfish produced in Florida can enter the major market networks that currently exist in Mississippi, Arkansas, and Louisiana.

In order for Florida freshwater aquafarms to be successful, markets must be established for these products. If farming is done on a large scale, markets other than local ones must be established. Because seafood markets for marine species exist, it might be beneficial for Florida farms to develop Florida-specific products. For example, striped bass hybrids are suitable for culture, and because one of the striped bass hybrid parents is a marketable marine species, hybrids could possibly enter marine market corridors.

The total retail value generated each year from ornamental fish shipped from Florida totals over 75 million dollars and 1 million boxes. Between 15,000 and 20,000 boxes of live fish are shipped by air each week from Florida. Potential buyers for Florida raised fish include large and small jobbers and farmer-wholesale suppliers. These suppliers subsequently sell and ship fish to regional pet shops. Pet shops require a wide variety of species, more than produced in Florida. For this reason, jobbers handle not only Florida fish but also imported species. Wholesalers, when possible, ship fish in full boxes to decrease shipment costs. In addition to the above mentioned distribution, some special breeders also ship fish; however, these breeders cannot usually provide the variety needed by pet shops. Local distributors transport fish by truck. These distributors may also handle dry goods and provide supportive services.

The tropical fish industry has been successful through established market channels. Advertising is done by direct mail, telephone solicitation, or advertisements in trade magazines. However, the tropical fish industry has faced serious problems over the past few years, which has resulted in loss of markets. The problems stem from the use of outdated technology and foreign competition. Upgrading culture technology by borrowing and employing practices common in other forms of fish culture will

improve farm efficiency and allow Florida farmers to offset competitive advantages now enjoyed by foreign sources of tropical fish. Florida farmers could also enhance their competitive position in the marketplace by learning how to culture additional species such as clown loaches, cyprinids (red-tailed rainbow, albino rainbow, bala, and black sharks), and red-tailed tinfoil barbs.

Sport- and baitfish are usually produced by small farms in Florida. Sales by these firms are usually accomplished through private negotiations which arise through telephone solicitation, personal contacts, and advertisement in trade magazines. Sale of live fish usually requires that the product be transported to the buyer. The buyer then becomes the producer of another product for recreational services (e.g. bait organisms).

If aquaculture of food and sportfish species is to expand in Florida, an improvement in marketing is required. Marine aquaculture products, through product development, might be channeled through existing markets. The tropical fish industry, through industry involvement and experience, has established a substantial marketing system. This system is actually quite sophisticated. Market improvement will come through development of increased international markets and by adding to product lines new species cultured in Florida. The expansion of markets, especially in Europe, would increase the tropical fish industry substantially. Sportfish and baitfish markets are usually developed through personal contact and advertisement in trade magazines.

Florida Aquaculture Species

Selection of the species used for aquafarming is important and can determine the success or failure of an operation. This list of species includes some species that might have potential as aquaculture organisms, but need additional research and development before they can be raised economically. Included in this discussion are species which are or have been used in Florida. This is not intended to be a comprehensive listing.

Tropical Fish

The tropical fish industry is centered in Hillsborough County, south of Tampa, with a much smaller center of some 35 farms extending from southern Dade County near Homestead, north to about Melbourne. Fish are grown for the most part in small earthen ponds, averaging about 2000 square feet in area and dug into the shallow water table to minimize water requirements. In hot weather, ponds may require aeration; in cold weather, they may require continuous pumping of deep, relatively warm well water and/or enclosing the pond with polyfilm to create a greenhouse effect. The fish are fed prepared rations that vary considerably in formulation and quantity applied. Antibiotics, drugs, and chemicals are used as needed for disease, pest, and weed control, but applications are far from standardized in the industry and tend to be administered from empirical observations.

There is some trend toward the use of aboveground tanks and ponds within greenhouse type buildings for at least the more delicate stages or species of fish, to provide some degree of temperature, predator, and general water quality control. Such intensification of management is directed towards the hatchery and nursery phases of the industry and for improved survival and cultivation of a broad spectrum of the more delicate species.

Research needs of the industry are in the areas of marketing and product promotion, reproductive biology (the ability to care for more species throughout their life cycle), genetics (selection for growth rate, size, disease and low temperature resistance, color and general appearance, and the ability to maintain these selected characteristics in pure breeding lines), nutrition (improved and less costly diets), disease diagnosis, prevention, and control, predator and aquatic weed control, general water quality control and management, and effluent management to ensure that exotic species do not escape.

The present domestic tropical fish market may be nearing saturation, but the ability to breed more species in captivity, species currently available only through import, would allow the industry to expand. There are also indications that wild stocks in many

foreign countries are becoming scarce and that many species from those sources may disappear from the market unless they can be reared artificially.

The single most important short range goal, with immediate benefit for the tropical fish industry in Florida, is the expansion of domestic and international markets, particularly into European markets. Expansion in new areas will allow the industry to garner a greater market share.

Presently, the farming of marine tropical fish in Florida is restricted to two or three growers producing two or three species. The marine segment of the industry is impeded somewhat by technological and biological constraints. Saltwater species are in high demand, however, and account for 10% of the total U.S. market and 20% of its value. Cultivation of more marine species is therefore a challenging technological problem that would expand existing markets and probably open new ones. The need for such cultivation of marine tropical fish can be expected to increase as more harvesting pressure is placed on the wild stocks.

Catfish

Channel catfish farming has become a successful aquaculture industry in many southeastern states. Although commercial catfish farming has been attempted here, several factors are responsible for this lack of industry development. A major problem for the commercial producer has been product marketing. Lake Okeechobee, the St. John's River, and several other large lakes and rivers of the state have traditionally yielded large quantities of bullheads (speckled catfish) for the consumer market. The in-state market for this wild-caught product has demonstrated a preference for a smaller-sized (2 - 5 oz.) dressed carcass commonly termed a "sharpie" by the commercial fish industry. In addition to marketing a product form not normally available from the farm-raised industry, the wild harvest of catfish and imports of wild catfish from South America has established a noncompetitive price in the market for cultured fish. Established catfish farming industries cultivate fish to the 1 - 2-pound round weight stage. This size fish suits markets in regions accessible to that industry. Marketing is presently the greatest constraint on the development of catfish farming in Florida.

Catfish products generally exhibit a "price elasticity" in the marketplace; this dictates that, if the price per pound is significantly increased over what the consumer is accustomed to paying, then a proportional decrease in volume of sales will follow. Farm-raised catfish products require a higher price in the marketplace than wild-caught catfish due to basic costs of production. Three states with viable catfish farming industries have passed "truth-in- labeling" legislation to distinguish cultivated products from wild-caught or imported fish and to protect the fish farmer's opportunity to compete in the marketplace. Although cultured catfish are considered a higher quality product than wild or imported fish, if product identification is the same for all catfish, aquaculture enterprise is at a disadvantage.

The lack of adequate processing facilities catering to Florida's farm-raised fish industry and the fact that in the past no commercial fish feed was produced in the state represented additional constraints on the expansion of the industry. Nevertheless, an important variable may be related to Florida's soil characteristics. Clay or impermeable soils suitable for large pond construction are available in the panhandle region, but sandy soils and high water tables are found in most of central and southern Florida. The cost of large pond construction in such areas creates a marginal investment for this production technology. Pond management practices of periodic draining and drying to allow for the decomposition of organic sludge that rapidly accumulates during intensive farming are not feasible in large ponds in the water table, but would be feasible in small fingerling ponds where organic accumulation can be removed.

A few small farms in Florida produce catfish fingerlings for sale to growers and owners of recreational ponds. These catfish hatcheries could also offer a solid business prospectus by producing seedstock for the more northern commercial industry earlier than is possible in that region. There are an undetermined number of small catfish farms producing fish for both recreation and food, but only three larger commercial operations have been started. In 1981, 275,000 pounds of food-size catfish products were raised on 87.5 acres. This represents a mean

annual production of 3200 pounds per acre per year, identical to average yields of pond production in the Mississippi delta region. Such information indicates that the previously mentioned environmental constraints facing the farmer in Florida may be overcome but with unknown additional production costs.

Tilapia

Species of *Tilapia* are of great importance in aquaculture, particularly in tropical-subtropical developing countries, and it is the dominant cultured genus in Israel and Taiwan, two countries which rely heavily on aquatic farming as a major protein source. The attributes which make *Tilapia* suitable for fish farming are general hardiness, resistance to diseases, high yield potentials due to resistance to overcrowding, and the ability to withstand low dissolved oxygen levels. *Tilapia* can utilize a wide range of natural and artificial feeds and, when reared under good aquatic farming practices, represent an excellent table fish with firm white flesh and no intermuscular bones.

Constraints on the development of *Tilapia* as a viable type for aquatic farming enterprise in Florida are in the areas of 1) marketing, 2) the technology required to cope with abnormally cold Florida winters, and 3) the technology required to resolve the issue of escape from aquaculture facilities. With respect to *Tilapia* culture, the regulatory environment has been created to reduce introductions of the nonnative fish and to minimize the opportunity for spread of wild populations. *Tilapia* have been referred to in the context of being a potential environmental hazard, resulting in regulations specifying design and construction criteria for the aquaculture facility and species permits for culture under terms and conditions of those regulations. In treating *Tilapia* culture farms under such conditions, regulations have done more to discourage the industry than to assist in its development. With respect to the marketing issue, the blue tilapia (*Oreochromis aurea*) introduced into Florida waters in the late 1950s has become an important commercial fish species in Central Florida, setting precedents for *Tilapia* pricing and edibility characteristics in the marketplace. This wild harvest of *Tilapia* has created a noncompetitive price for potential fish culturists.

Research by industry and institutions with *Tilapia* hybrids has created the phenotypic red coloration in certain genetic lines and hybrids that can provide the consumer with an obvious color indicator to distinguish wild-caught fish from the domestically cultured animal in the marketplace. Hybridization of *Tilapia* species has become a common practice in the international aquaculture community to improve wild stocks and to create genetic varieties suitable for domestic aquaculture. Institutional research with hybrids is stimulating the development of private industry in other southeastern states.

Another major constraint to commercial cultivation of *Tilapia* is early sexual maturation and the inclination of the species to spawn regularly which may result in overpopulation and stunting in conventional pond production systems. Research to control these phenomena has been in the area of hybridization of pureline species to produce monosex populations and the use of androgen hormones in the early life cycle to sexually differentiate postlarvae into all male populations. Research on reproductive control is continuing on a broad international front but no work has occurred in Florida.

Cultivation of the non-native *Tilapia* in Florida may be done only by Florida Game and Freshwater Fish Commission permits, of which 24 have been issued, eight for research and the rest for commercial culture. The majority of commercial permits are currently inactive. Certain *Tilapia* aquaculture enterprises employing high-density culture techniques and improved red hybrid stocks have demonstrated the marketability of this species. There are existing water bodies in Florida where *Tilapia* might be grown economically in cages or pens.

Alligators

Intensive alligator culture is a new industry in Florida encouraged by the legal protection of the species and the worldwide effort to control diminishing crocodilian populations. At present there are 18 farms in the state in various stages of development. Investment in these farms is well over 4 million dollars with many in their start-up phase. The

animals are sold for their hides (presently $23-28 per foot) and their meat ($5-per pound). Over the three year period of 1985-1987, these farms are projected to harvest approximately 16,000 animals for combined gross sales exceeding $5 million at today's prices.

Alligators grown intensively reach a marketable (at present) size of six feet (60 pounds in three to four years. During this time they are fed a variety of mostly waste meat, fish, and poultry products. Yields of about 500 animals per acre (3000 ft of hide, 10,000 lbs of marketable meat) can be achieved over this growth period.

Cultivation of the species, both biologically and economically, hinges on the continued development of advanced alligator husbandry techniques and technology. Only a small amount of research has been conducted over the last four years in Florida on intensive alligator culture. Most of this research has been conducted through the University of Florida (IFAS) and is financed by the Florida Alligator Farmers Association. Results have been very encouraging. For example, preliminary nutrition research has shown that a length of nearly four feet can be achieved in the first year, thus producing a marketable six-foot animal in two rather than three to four years.

A program jointly sponsored by the Florida Alligator Farmers Association, Florida Game and Fresh Water Fish Commission, and the University of Florida (IFAS) is showing (in the early results of a five-year study begun in 1981) that a percentage of alligator eggs or hatchlings can be removed from populated alligator habitats and can be placed in commercial grow-out facilities. This research is expected to show that a sustained, controllable alligator population can be achieved and also provide the alligator culturist with a supply source. Successful artificial insemination research has provided information in the area of captive breeding and reproduction. Superior, faster growing animals have been produced through this method.

This limited amount of research, coupled with existing working operations, has shown that intensive alligator cultivation is feasible and practical. However, low reproductive efficiency and high embryonic death on farms with captive breeding programs, high start-up costs (the average farmer waits three to four years before receiving a return on his investment), availability of broodstock and hatchlings, and high costs and market instability are some of the areas concerning and depressing the expansion of the industry.

Alligator cultivation has the potential to become an important industry for Florida, providing jobs and a new source of untapped revenue. With wetlands utilization, with the alligator as a renewable resource, and with proper funding for research and development of markets, it is foreseeable that the industry can become a major aquaculture industry within the next decade.

Improvement of technology is needed in the areas of captive breeding, nutrition, and disease prevention and control, but no major technological problems constrain the development of the industry, which expects to double or triple by 1990, a goal that would require the production of more than 40,000 animals annually. Still further expansion is anticipated beyond 1990 but this would require penetration of the world market for crocodile and other reptile hides, a strong probability in view of increasingly effective international protection of such species.

American Eels

Eel culture, although widely practiced in the Far East and Europe, is in its infancy in the United States where only a few eel farms exist. A wild fishery for eels does exist in the U.S. with an estimated production in excess of 6 million pounds per year which is roughly equivalent to the output of cultured eels from Italian farms. Production of wild eels in Florida is estimated to be 250,000 pounds per year average. Although most eels are exported to Europe from the U.S., a domestic market does exist for 4 - 9-inch fingerlings which are considered excellent bass bait and for adult (one-half pound or more) eels as food in cities with large European or Oriental ethnic populations.

Eels are not routinely spawned in captivity. The Japanese have done *in vitro* fertilization and have reared larvae for five days. Russian scientists have obtained fertile eggs from eels grown in captivity. All commercial eel farms worldwide depend on elvers

captured on their upstream migration as a starting point for the culture operation. They are usually captured with traps or nets. No evidence exists to suggest that taking of seedstock from the wild will deplete the resource.

Eel culture is being conducted in Florida using methods similar to those employed in Japan. Juvenile eels are captured by dip net from local waters and transported to the farm. Following disinfection with formalin to remove parasites contracted in the river, the juveniles (250 eels/pound) are placed in fiberglass tanks measuring 5 x 11 x 1 1/2 feet where they are fed a natural diet of crab eggs, fish eggs, etc. Gradually over a period of weeks, the eels are weaned to a compound fish diet which has fish meal as the major component. As the eels grow to a size of 100 eels/pound, they are transferred to larger circular fiberglass tanks 15 feet in diameter with a water depth of 3 feet. Eels are sorted every six weeks during the grow-out period. Bait-size eels are available in four to six months, and food-size eels are ready in 1.5-2.5 years.

Cultured eels can bring a farm price of $2.50/lb which is about $1.00/lb more than similar-sized wild eels. Cultured eels are considered a better product because of a higher fat content which keeps the flesh from drying excessively when cooked (smoked). Bait-size fingerlings may wholesale for $4-8 per dozen. Most eels are shipped live to market, but may be frozen and/or processed.

Constraints on eel culture in Florida include in order of priority 1) lack of a steady supply of juveniles, 2) lack of basic nutritional research, 3) lack of expertise and facilities for disease research, 4) lack of research on the male-female sex ratio as it affects growth rates, 5) lack of adequate nonstop flights to Europe and Japan from central and north Florida, 6) regulatory conflicts between the Game and Fresh Water Fish Commission and Department of Natural Resources due to the catadromous nature of eels, and 7) lack of marketing information and research.

Florida is an ideal location for eel culture because of climate and abundant ground water. Although eel production costs are high owing to feed, equipment, labor, and energy, the value of eels is high enough to have a profitable operation.

For food-size eel culture to be profitable, nutrition research, to reduce the conversion ratio and thus bring the price of cultured eels to a value comparable to the wild product, must be conducted. Spawning research should take low priority until the traditional way of obtaining seedstock is ensured and basic nutritional research is conducted. Marketing would be a small problem if the sales price of cultured eels were comparable to that of the wild product.

Because survival of juvenile eels is substantially increased under culture conditions, large quantities of cultured eels can be produced with virtually no ill effect on the wild fishery. Cultured eels can fill shortages in the market during the winter months, and fingerling eels can be used as bait for bass fishing.

It is estimated that a 30-acre intensive eel culture farm can produce 100,000 pounds of food-size eels per year and employ three people. Several eel farms of this size could operate in Florida without depressing the market price.

Striped Bass/Hybrids

Hybrid striped bass result from a cross between female striped bass *Morone saxatilis* and the white bass *Morone chrysops*. The reciprocal cross also produces a viable hybrid. Institutional research in other states with the striped bass/white perch *Morone americanus* hybrid is underway as well. Striped bass ranks as one of America's most desirable game and food fish species. Striped bass/white bass hybrids have demonstrated hybrid vigor in growth rates, disease resistance, improved survival, and better overall hardiness. These hybrids also have become popular as a recreational species and valued for their food qualities. Hybrids have outstanding potential for culture as a food fish in Florida.

Commercial landings of striped bass on the eastern seaboard have drastically declined since 1973. In 1982, landings from North Carolina to Massachusetts were only 15% of the 1973 level. Current mandatory recommendations of the Interstate Fishery Management Plan call for a 55% reduction in fishing rates. Commercial fishing for striped bass in Florida is prohibited. Concurrent with the decline in the availability of striped bass, the demand for striped bass in the marketplace has increased five-fold since

the early 1970s. The characteristics of this demand and the pricing structure of striped bass products in the marketplace create opportunity for aquaculture enterprise. The demonstration of aquaculture potential for striped bass hybrids is currently underway in other southeastern states. Work with striped bass hybrids in Florida has been restricted to providing seedstock for recreational fisheries although the fish have been successfully reared in ponds, raceways, and pens in marine environments. Commercial sale of the fish in Florida is restricted under current regulations. The hybrid's status as a game fish is presently under revision to allow its culture and sale as a food fish.

Spawning in captivity is a routine procedure by using hormones and stripping the eggs from the ovulating female. Striped bass can spawn naturally in circular tanks, but manual methods are used to produce hybrids. The acquisition of gravid broodstock represents the greatest constraint on private hatchery development as state and federal hatcheries have taken the position of not supplying the commercial industry with seedstock. The availability of seedstock for private industry represents a limiting factor for aquaculture development of the species.

Production of phase I fingerlings from larvae is the most critical stage in the culture of the animal because survival is influenced by the natural food in the aquatic environment used to cultivate the postlarval fish. Training phase I fish to accept prepared rations is important to producing phase II stocker fish for grow-out ponds. Conventional pond production of hybrids for food fish will benefit from greater availability of phase II stocker fish.

Hybrid bass culture offers good potential to develop a food fish industry for Florida. However, production technologies suitable to the breed's biological requirements and particular market demands need research and identification. Conventional freshwater pond production methods of annual stocking and harvesting may not produce a fish of the size and character required by the market. Recent market testing by private industry has indicated that a pan-size 1-pound fish is not marketable at premium prices common to striped bass markets. The preferred sizes for this type fish are in the 3-4-pound range. Production technologies and market studies must address this issue when one considers a commercial enterprise with this species.

Sport Fish

Fish farms can produce sport fish (largemouth bass, bluegills, redears, etc.) and the potential for this type of farm is good although only a few farms currently exist. The Florida largemouth bass is an ideal species for export to other states with moderate climates. Northern species (spotted bass, walleye, smallmouth bass) could be imported for spawning purposes during the fall and winter, and then the fingerlings could be shipped north before that species spawns in more northern waters. Producing stockers for marine recreational fishing (snook, trout, redfish, etc.) may become an aquaculture business in the future. The industry could be expanded considerably if governmental agencies did not compete with the private sector. Coordination and leadership are needed by state agencies to resolve such constraints.

Baitfish

The culture of baitfish began in the early 1900s; however, significant progress and expansion were not attained until the 1950s and 1960s. Most baitfish are cultured in freshwater and as a result most available information is derived from the freshwater baitfish industry.

The baitfish industry in Florida is not large. The primary fish raised is the golden shiner, with limited fathead minnow production. The fish are sold primarily to bait dealers Who finally sell them to recreational fishermen. Presently the majority of baitfish are brought into Florida, but could be cultured here.

This portion of the industry can be expanded considerably, especially in the area of new species development. In the freshwater area, for example, eels, freshwater shrimp, and crawfish culture should be investigated. Saltwater fishermen also fish with live bait, most of which is trapped in shallow estuarine areas. Penaeid shrimp, killifish (*Fundulus grandis*), and mullet are likely candidates. Research and development are needed, however, for the industry to prosper.

Chinese Carp

Grass carp *Ctenopharyngodon idella*, bighead carp *Aristichthys nobilis*, and silver carp *Hypopthalmichthys molitrix* are all potential candidates for aquaculture. These species, especially the grass carp, are valuable for biocontrol of algae and macrophytes and are used for this purpose over much of the world. Both the bighead and silver carp consume algae and are used as a biological control for these plants. The food value of these fish has not been fully realized in the U.S., but a market exists in metropolitan areas with large oriental ethnic populations.

Chinese carp are easily spawned in captivity through hormone injections and can be grown to stocking or food size rapidly, using vegetation and prepared food. Procedures exist to produce sterile triploid grass carp, and sterile fish may be used in Florida for weed control.

For this species to be cultured in Florida, procedures must be established whereby fish farmers could produce only sterile triploid fish. Verification of sterility would have to be made before fish were sold, and permits from the Freshwater Game and Fish Commission are required to possess these fish.

Aquatic Plants

Aquatic Plants for Aquarium Use: In the state of Florida the cultivation and harvesting of aquatic plants represent a well established, viable industry that generates 5 million dollars yearly. Farmers need only regulatory encouragement and support to double that figure.

Florida is the only state where aquatic plants can be commercially grown profitably because of its favorable climate and ease of transport via air freight. Plants are shipped to all areas of the U.S. and Canada, as well as to many locations in Europe, where the aquarium hobby is very well developed.

The industry is constrained by the following:

1. Importation of plastic plants from the Far East;
2. Need for a facility for taxonomic identification, growth problem research, and disease identification and treatment; and
3. The need to coordinate all government activities regulating and affecting the aquatic plant industry.

Industry and government are in agreement that state waters should be kept free of obnoxious aquatic weeds. Many exotic plants presently found in the state have been present for 30 years and it would be a benefit to all concerned if commercial uses were found for these plants.

Aquatic Plants for Food: The potential exists for aquatic food plant production to become a rewarding endeavor in this state. The climate, the vast wetland areas, and crop demand interact to create an optimistic outlook. However, this industry segment needs research and development to succeed.

Presently, there are 10,000 acres of rice being cultivated in the Everglades Agricultural Area. Rice culture developed because of a need to slow the subsidence of organic soil in the area. Further research in this region on aquatic plants could help to preserve natural peatland while continuing to produce food and fiber for future generations.

There are a demand and ready market for certain aquatic food plants. The following plants have food value and economic importance in developing countries, especially in the tropics, and also have potential for Florida aquatic plant growers.

Floating rice (*Oryza sativa*) is grown over much of Asia in areas where water depths are too great for standard rice varieties. Seeds are broadcast on a dry or moist soil before the rainy season. As the water rises the plants grow to keep up with the water level. Up to 3 tons per hectare are produced; however, yields might be increased through research into varietal selection, factors that limit production, and genetic improvement. In Florida, growing sites must be determined.

Wild rice (*Zizania aquatica*) grows in Canada and the western U.S. and is cultivated for market. Field tests over a three-year period at Belle Glade indicate that this crop can be successfully grown in Florida.

Taro (*Colocasia esculenta*) is grown for its tuberous roots which are used in certain areas of the

tropics as a carbohydrate food. Roots are used as rice substitutes in Pacific and Asian countries. The flesh is mealy and has a nutty flavor. Flour can be made that is used in baby foods and hypoallergenic foods and as a cereal substitute for people suffering dietary problems. In Hawaii a paste is made called *poi*. It is also sliced and fixed into taro chips.

Taros require hot humid conditions with an average daily temperature of 69.8-80.6°F (21-27°C) and must have a 6-7-month frost-free period. The plant responds well to intensive agriculture and in Hawaii may bring an income of $4000 per hectare. Water control is necessary. Another species, swamp taro (*Cyrtosperma chamissonis*), grows in both fresh and brackish water with little care, but grows best in slowly moving water less than 1 m (39.37 inches) deep.

Taros could be an aquatic crop for Florida if proper varieties are selected, disease research is undertaken, and genetic improvement is developed. Mechanization of the industry is also needed to improve crop management and harvest. Taro could be processed to develop hypoallergenic specialty foods.

Lotus (*Nelumbo nucifera*) is another plant that has edible rhizomes and seeds. It is commonly eaten in the Orient and the rhizomes are in demand among Chinese populations. The rhizomes can be harvested after 9 months and yields up to 4600 kg per hectare have been reported. This plant grows in standing water and mud with very little land preparation. If a market is established in the U.S., the lotus might be a suitable plant for Florida aquatic plant growers.

Arrowhead (*Sagittaria trifolia*) corns, which are about the size of water chestnuts, are boiled and used like potatoes. Oriental cooks use the corms in meat dishes. This plant grows wild over much of Asia and is often considered a weed. U.S. species *S. sagittifolia* also has potential crop value. Research is needed to determine market potential in U.S. oriental markets.

Chinese water chestnut (*Eleocharis dulcis*) is probably one of the most well known of the tuberous plants used for food. The tubers from this plant are sold in international markets and bring high prices. Water chestnuts are a common ingredient in Chinese meat and fish dishes. This plant is cultivated in flooded fields. Small tubers are obtained from nursery stock, raised in beds, and transplanted to fields where they are allowed to grow for six months prior to harvest. Yields can exceed 7 tons per hectare. This plant is currently grown in the southern U.S. and is a potential plant for Florida growers.

Watercress (*Nasturtium officinale*) is a member of the mustard family and native to Europe and northern Asia. It is widely cultivated in temperate and tropical regions. It is eaten as a fresh salad vegetable or a cooked green vegetable. Research would be needed to locate desirable cultivation areas and plants with greater temperature tolerance.

Spirulina (*Spirulina platensis*), a blue-green alga, is cultured for animal and human food. This plant is very high in protein (up to 72%) with a good balance of amino acids. Because it is a large algae it can be recovered through filtration. A production system for *Spirulina* currently exists in Mexico where 5 tons (dry weight) are produced daily. This product is used as food for livestock, but can be used for a meat substitute or a protein complement. Under optimum conditions the yield of protein from *Spirulina* may be 10 times that of soybeans. Research into mass cultivation techniques is needed, and improvement of harvesting and processing techniques must occur to decrease costs. Feeding tests are also required to determine safety and acceptability of the product.

The above list does not include all aquatic plants that have been used or have potential for human food, nor does it include plants that can be used solely for animal foods. *Spirulina*, in addition to its value for human populations, has potential as animal feed, especially for tropical fish and birds, because it enhances their color when placed in food. Other plants such as water hyacinths, cattails, and duckweeds might have value for water purification and energy production. Cattails and duckweeds have also been used for human food. Currently such plants as water chestnuts, watercress, and taro have economic importance in the U.S. Potential crops must also be evaluated, not only for wetland cultivation, but also for minimum labor and fertilizer requirements, marketability, and environmental com patibility.

Certain species of marine algae are high-priced luxury foods in Far East countries. Others contain

gelatinous polysaccharides (agar, carrageenin) that are extracted and used as emulsifiers and stabilizers in the food, drug, cosmetic, and other industries. Still others produce hydrocarbons, glycerol, and other unusual chemicals that may be used for fuel, chemical feedstocks, and other industrial purposes.

All of the above may be grown in Florida, in most cases better than elsewhere in the world, due to the region's high incidence of solar radiation, benign climate, and abundance of freshwater and marine habitats. Most of the aquatic plants described have, in fact, already been grown in Florida, at least on an experimental basis. There is presently a small commercial watercress farm and an ornamental aquarium plant industry in the state.

Aquatic plants, grown for food or for industry, for local consumption or for export, are another example of potentially high-priced specialty products of aquaculture that may be particularly appropriate for Florida.

Crustacea

Penaeid Shrimp : Shrimp are an extremely valuable fishery product in the U.S. The consumer market exceeds 1 billion dollars which is probably limited by supply. White (*Penaeus setiferus*), pink (*P. duorarum*), and brown (*P. aztecus*) shrimp are the three commercially important species.

In 1983, nearly 60% of all shrimp consumed in this country were imported. Shrimp consumption is projected to increase while harvests from natural stocks are approaching their maximum sustainable yield. Prices will continue to rise due to increased demand, limited supply, and escalating cost of fuel. Shrimp farming, therefore, will play an increasingly important role in supplying shrimp for the U.S. market. In 1983 Ecuador exported over 50 million pounds of farm-raised shrimp into the U.S.

Using methods developed in Japan, gravid female shrimp of all the local marine species can be spawned routinely and the young reared to maturity in captivity. A chronic problem, however, was the inability to achieve sexual maturation of captive adults; gravid females were obtained from the commercial fishery. Through the establishment of separate research facilities in Florida by two major companies engaged in shrimp culture, that problem has gradually been solved and each company now has the ability to rear any species of shrimp through its entire life cycle.

Commercial cultivation of shrimp in coastal embayments, ponds, and tanks along Florida's coastline, however, has proven uneconomical. Thus, the industry has moved to Central and South America, where extensive estuarine pond systems may be inexpensively built and operated. Shrimp culture in that part of the world, now successfully and profitably practiced by a number of large U.S. firms, is an interesting example of the "deintensification" of aquaculture. The small, densely stocked tanks and ponds dictated by the high land costs in Florida required rapidly circulating and frequently exchanged seawater and heavy feeding with costly, artificial, pelleted feed. Such systems have given way to extensive pond systems in Latin America, similar to those used for many years in Southeast Asia, in which sparse natural populations of shrimp larvae, brought in with the seawater while filling the ponds, grow naturally with little or no supplemental feeding. Three crops per year may thus be reared in that tropical setting. Yields are low, 1500 pounds per acre per year or less, in contrast to 3000 pounds per acre per year in the more intensive systems formerly used in Florida. In Latin America huge areas and the manpower to farm them are cheap and profits are high.

The maturation laboratories in Florida not only developed the technology for rearing the postlarval shrimp in captivity but also provided the young for their own grow-out facilities in Latin America until they were able to build hatcheries at the farm sites, as one of the companies has now done. Two hatcheries currently exist in Florida and are selling postlarval shrimp.

There remains a secondary role for shrimp aquaculture in Florida. The sizeable bait industry for sports fishing requires live animals that normally come from the shrimp fishery. These live shrimp, considerably smaller than those normally marketed as food, command a significantly higher per capita price. They are also unavailable from the fishery during the warmer months when sports fishing is particularly active. Cultivation to bait size, which could be done in

60 to 90 days at little cost during the warmer months, could be a profitable small industry in Florida. Improved methods of handling and transportation (i.e. packing the live animals in dry sawdust, as is done in Japan, rather than moving them in large, aerated water tanks) could materially decrease transportation costs and increase profits of such an enterprise.

There are many technical areas of shrimp culture that can be improved through research. More needs to be known about natural reproduction and nutritional requirements of different species even though much has already been discovered and is presently being applied. Comparative studies on growth and behavior of different species under different culture conditions are needed. Least cost diets for specific species need to be developed for each stage of growth and for different culture systems. More information is needed on predation and control of diseases. A lack of sites and competition - for available sites have constrained development as has the complexity of the permitting process. Inclusion of mariculture into coastal zone planning could minimize these constraints.

Macrobrachium: Culture of the giant freshwater shrimp or prawn (*Macrobrachium*) in Florida has suffered from many of the same problems as has penaeid shrimp culture. In addition, *Macrobrachium* is a truly tropical species and does not survive even in southern Florida under normal winter conditions. Several attempts to grow *Macrobrachium* in Florida in the past were unsuccessful, and no one is attempting to do so in the state at present.

However, aquaculturists in several other southern states have approached *Macrobrachium* as a seasonal (summer) crop, maintaining broodstock indoors in heated facilities in winter or, more commonly, buying post-larvae in the spring. If that practice proves profitable further north (e.g. the Carolinas), it should be even more so in Florida with its longer growing season. Aquaculturists growing other species (tropical fish, *Tilapia*, catfish) should be made aware of this possibility and of the success achieved in other countries (e.g. Israel) and elsewhere in the U.S. (Hawaii) of polyculture systems involving the culture of *Macrobrachium* and nonpredatory fishes. Sources of *Macrobrachium* postlarvae should be identified and the information made available. Perhaps one hatchery in Florida would prove economically viable for producing postlarvae to aquaculturists both within and outside the state. Possibly such a facility could be combined with a penaeid shrimp hatchery for the same purpose. A marketing survey of the entire field (marine and freshwater) would be useful.

Other Crustacea: The Florida (spiny) lobster has never been grown in captivity throughout its long and complex larval life cycle. Post-larvae can be captured in large numbers with suitable collecting devices in coastal waters, particularly around well protected embayments, during most of the year. These could be grown in captivity to normal market size for the species or even to a smaller size (e.g. comparable to large penaeid shrimp) for a specialty restaurant product (such as lobster cocktail). However, legal problems of catching post-larvae, growing the species in captivity, and marketing small or out of season shellfish would need to be resolved.

The stone crab has now been reared throughout its life cycle in captivity and should be considered a candidate species for aquaculture in Florida. More research is needed. however, before its commercial potential can be assessed. The problem of cannibalism, common in all clawed crustacea, particularly needs to be considered. The feasibility of "ranching" large populations of stone crabs reared in captivity for periodic harvesting of their claws might also be investigated. Stone crab post-larvae may also be captured from the wild using the same methods as described above for lobsters.

Mollusks

The discussion provided here reflects only current conditions and takes no note of perhaps hundreds of mollusks that conceivably could be cultivated for human food or for some other purpose at a later date. The few that receive attention do so because they appear to be the most likely to be farmed when aquaculture begins to find its rightful place in Florida's economy.

Oysters: These shellfish have a long history of cultivation in Europe, Asia, and Australia. More research probably has been done on them than on any other saltwater creature. Hatchery and growout methods are well developed and there is a bright future

for oyster farming in Florida, if present impediments can be removed, but these are imposing. First, there is a policy unfavorable to the concept of oyster leases within the Department of Natural Resources; second, there is no strong tradition of private lease cultivation in Florida as there is in such states as Louisiana and Washington; third, the oyster industry generally is very conservative and basically unwilling to engage in a departure from traditional methods of operation (i.e. harvest from public reefs); and fourth, the industry is composed of mostly small, sometimes almost cottage-sized, operators who would have great difficulty financing an oyster cultivation enterprise.

Oyster cultivation holds the greatest potential for marine aquaculture in Florida. Florida could easily produce enough oysters to satisfy the present demand nationwide and have sufficient supplies remaining to develop a foreign export market. A need exists to develop methodology for construction of artificial reefs. A demonstration program evaluating new and existing reef construction methods, developing off-bottom culture methods suitable to Florida, establishing economic feasibility, and monitoring environmental factors correlated with community settlement, succession, and climax should be a high priority.

Clams: As with oysters, there is precedent for clam farming in the U.S., but it is a much more recent development. Hatchery methods are well perfected and provide virtually all of the seed that is planted on clam leases, which are few in number in the U.S. and now nonexistent in Florida. Development of private clam farming has the same problems and same solutions as those of oyster cultivation. Clam farming also has potential in Florida.

Queen Conch: The queen conch (*Strombus gigas*) provides subsistence for human populations of the Caribbean areas where it is found and, as it becomes a luxury item of importance, it is increasingly being exported to the U.S. The same demand has resulted in overfishing of Florida stocks that are found in waters off the southernmost part of the state. Wherever it exists it has been overexploited.

To sustain production and perhaps to increase it, the possibility of cultivation, using hatchery-reared stock, has been investigated. So far, no attempts have been made to stimulate spawning. Rather, egg capsules have been brought into the laboratory where embryology, hatching, planktonic life, and juvenile production are under controlled conditions. While present exploratory methods are considered to be uneconomical, it is expected that further studies will refine them and make them more practical.

Scallops: Two species are currently caught commercially in Florida, the calico scallop and the bay scallop. The latter is an important recreational resource. The calico lives offshore in waters 5 to 200 fathoms deep. It has not received any attention from the standpoint of cultivation, but has recently become an established commercial fishery product on the east coast.

Bay scallops, being easily available close to shore and having a very long range (Nova Scotia to the northern parts of both coasts of Florida), have been the subject of strong research effort from scientists interested in their cultivation. This has been found to be a very promising species for farming and techniques for artificial spawning and grow-out have been developed. No commercial scale ventures or demonstrations have been attempted, nor has the economic feasibilitv been established.

Marine Finfish

Florida undoubtedly leads the country in the number of unsuccessful attempts at commercial marine finfish aquaculture. Most marine fishes have extremely small eggs and larvae that are difficult to feed and rear in captivity. Gradually, however, these problems have been solved in the United States and elsewhere, and now a host of marine finfish species, including several species of grouper and snapper, red drum, black sea bass, dolphin, and seatrout, can be grown routinely throughout their entire life cycle in captivity.

Dolphin, the culture of which was developed independently in North Carolina and Hawail, is a particularly attractive species. Gravid fish can be captured throughout the year in Florida. They are easily managed, they can be sexually matured and easily spawned in captivity, and the larvae can be reared with low mortality rates. The young feed on a variety of natural foods including fishery wastes and

have a high food conversion efficiency. Most striking, they grow rapidly, attaining a size of 3 lbs in as little as three months, much faster growth than any other fish now in culture. Pilot projects assessing production yields per unit area, use of artificial feeds, and other commercial considerations are now locally in progress.

If pilot testing of dolphin culture appears promising, commercial application in Florida could follow. More likely, the culture methodology will be another example of technology transfer to other areas where inexpensive coastal land and labor and other advantages exist.

Other highly desirable marine finfishes, such as red snapper, await similar pilot-scale evaluation of their commercial culture potential. Some of these command a price (several dollars per pound) that puts them in a far different class from catfish and *Tilapia* and could make their cultivation profitable even in high-value coastal areas of Florida.

In order for the marine finfish industry to develop, expanded information is needed pertaining to selective breeding, larval rearing, nutrition of larval fry, fingerlings, and adults, demonstration of production methods and capabilities, and location of commercial sites. The potential of hatcheries to produce stocker-size fish to enhance marine recreational fisheries should be investigated.

Florida leads the nation in the number of artificial reefs. Research efforts are now being consolidated to optimize this practice of habitat enhancement. Part of that effort is toward designing reefs for production of targeted species. The possibilities of artificial reef development in the context of commercial aquaculture leases and ocean ranching operations should be explored.

Marine Algae

Certain species of unicellular algae (phytoplankton) and macroscopic algae (seaweeds) have potential or existing value as human food, animal feed, soil conditioners, fertilizers, and biomass for conversion to fuel and for their chemical constituents such as pigments, biologically active compounds useful as pharmaceuticals or agricultural agents, and gelatinous polysaccharides (agar, alginic acid, carrageenin) widely used as emulsifying or suspending agents in the food, drug, and cosmetic industries.

Large-scale algae culture for these various purposes is already a reality in several other countries as well as in other parts of the United States (California, Hawaii). Its mild climate and abundant sunshine make Florida particularly well suited for such aquaculture practices. Basic knowledge is needed pertaining to storage and procurement of seedstock, seaweed production potentials, fertilization strategies and nutrient requirements, and engineering strategies. Lack of marketing information for this broad and complex field is a primary constraint.

Summary

The tropical fish industry illustrates that intensive aquaculture for specialty, high-value products can be highly successful in Florida. Similar efforts should be equally profitable in the following areas: cultivation of luxury foods, chemicals, drugs, and fuels; production of post-larvae and fingerlings for export to aquaculture projects outside Florida; sports fishing, bait, and other uses; and development of a modern aquacultural biotechnology for food organisms; for local consumption where appropriate, but particularly for export.

The high-priced, high-demand "luxury" food species might be grown profitably in Florida. Recent technological advances in the controlled spawning and larval rearing of marine finfishes, together with their rapidly escalating value, may make such species as pompano worth a second look. Dolphin, red snapper, and striped bass fit into the same category.

More favorable prospects may exist for the few species that combine high value with a position low on the food chain. Littleneck clams and penaeid shrimp are good examples of species that can be grown extensively, with little or no extraneous feeding or management. Unfortunately, in such practices, one trades the high cost of food and management for that of the required large areas of coastal wetlands. It is for that reason that the penaeid shrimp industry has migrated to the vast uninhabited estuarine regions of developing Latin American countries. There may,

however, be room for modest operations of this kind in Florida if restricted coastal areas can be designated and protected for that purpose, or for more intensive culture operations. The state has, in fact, a far-sighted aquaculture law and policy with respect to the leasing of such sites for aquaculture, though its implementation has been severely limited.

On the other hand, the repeated lack of success in growing conventional, moderately priced food species, freshwater or marine, and the absence of any significant aquaculture-for-food industry in the state suggest that there may be special problems in Florida despite its long coastline, extensive freshwater resources, and seemingly benign climate. Most of these problems have been identified and need to be investigated.

We submit that there are such problems but that they are, for the most part, social, legal, and economic rather than technical. Some, such as the high value of coastal lands and the heavy and often conflicting demands upon coastal and inshore waters, are facts of life that will not change except to the further detriment of aquaculture and its prospects. Others might be resolved or ameliorated by appropriate legislation or other means that would create a more favorable climate in the state for aquaculture development.

Additional Information

The information presented in this publication is a bare overview of the knowledge and resources (both financial and natural) that one would need for a profitable aquaculture venture. More specific information can be obtained through local Cooperative Extension Service offices or Sea Grant Extension Agents. Extension publications currently being produced include Aquaculture in Florida: Some General Economic Considerations, Management of Water Quality for Fish, Weed Control in Aquaculture and Farm Ponds, and Introduction to Fish Parasites and Diseases and Their Treatment. Other Extension publications will continue to be developed. Cooperative Extension Agents can also refer to experts in other state or federal agencies, such as the Game and Freshwater Fish Commission, Department of Natural Resources, Department of Agriculture and Consumer Services, and the Soil Conservation Service.

Table 1.

Table 1. Regulations Affecting Aquaculture.

Agency*	Statute or Rule	Description	License, Permit, Lease
GFC	372.0225 FS	Regulate aquaculture facilities	Yes
	372.76 FS	Search, inspection, seizure	
	372.83 FS	Penalties for violations	
	39-23.09 FAC	Sale and transportation of fish	Yes
	39-12.09 FS	Killing depredating birds	Yes
	372.65 FS	Fish farm, wholesale, and exotic dealers	Yes
	372.26F5	Imported fish	Yes
	39-405 FAC	Non-native fish	Yes
	370.112 FS	Striped bass possession	Yes
	39-23.08-12 FAC	Non-native protection devices	Yes
	39-4.05 FAC	Diseased fish	
	39-23.08 FAC	Diseased fish	
	39-25.04 FAC	Alligator farm operation	Yes
	39-25.05 FAC	Harvest and sale of alligators	Yes
	39-25.07 FAC	Sale of alligator products	Yes
	39-25.051 FAC	Sale of alligator meat	Yes
DNR	370.16 FS	Shellfish leases	Yes
	253.67 FS	Water column leases	Yes
	161 FS	Beach and shore preservation	Yes
	16B-28 FAC	Shellfish sanitation	
	16C-52 FAC	Aquatic plants	Yes

Table 1.

USEPA	PL95-2174OCFR 121425	NPDES discharge	Yes
DER	403 FS	Water quality discharges	Yes
	17-4, 17-1217-45 FAC	Dredge and fill	Yes
	PL92-583, 380 FS	Coastal zone management	
WMD	373 FS	Consumptive use water	Yes
	373 FS	Storage and management surface water	Yes
	373 FS	Wells	Yes

*Abbreviations: GFC = Florida Game and Fresh Water Fish Commission; DNR = Florida Department of Natural Resources; USEPA = U.S. Environmental Protection Agency; DER = Florida Department of Environmental Regulations; WMD = Water Management District; NPDES, National Pollutant Discharge Elimination System.